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| <br><b>Weatherford®</b> | <b>MATERIALS SPECIFICATION</b> |                    |                         |                          |                    |
|                                                                                                          | REV:<br><b>AU</b>              | SECTION:<br>Steels | NUMBER<br><b>WS-412</b> | Prepared by:<br>W. Howie | PAGE<br><b>1</b>   |
| TITLE:<br>4130 – 4145 Steel - 110 ksi Min. Yield Strength                                                |                                |                    |                         |                          | DATE:<br>9/14/2021 |

## 1.0 SCOPE

- 1.1 This specification pertains to the 41XX family of low alloys steels from 4130 through 4145 in the heat treated (quenched & tempered) condition. Material meeting the requirements of this specification shall exhibit a minimum yield strength of 110 ksi. This material and strength level is generally not suited for sour H<sub>2</sub>S service. The Grade selection is based upon a variety of factors including section size and whether welding will be performed. Note that preforming or blanking is often required to achieve the specified mechanical properties. When there is an apparent conflict or difference between this specification and a referenced specification, this specification shall govern.
- 1.2 When required by Purchase Order or Engineering Document, there are Supplemental Requirements that are applicable and defined herein. A suffix attached to this specification (such as WS-412-S1S2) adds the contents of the supplements listed to the specification requirements.
- 1.3 For the Liner Hanger Product Line or with Engineering Approval, WS-506 (Ni-Cr-Mo steel with 110 ksi minimum yield strength) is an acceptable substitution for this specification when bar diameters are greater than 6". Note that all of the specified requirements herein including the activated supplemental requirements shall be met when substituting the WS-506 specification for this specification.

## 2.0 REFERENCED SPECIFICATIONS

- 2.1 ASTM A255: Test Method for Determining Hardenability of Steel
- 2.2 ASTM A370: Mechanical Testing of Steel Products
- 2.3 ASTM A388: Recommended Practice for Ultrasonic Examination of Heavy Steel Forgings
- 2.4 ASTM E587: Standard Practice for Ultrasonic Angle-Beam Contact Testing
- 2.5 ASTM A751: Test Methods, Practices and Terminology for Chemical Analysis of Steel Products
- 2.6 ASTM E10: Test Methods for Brinell Hardness of Metallic Materials
- 2.7 ASTM E18: Test Methods for Rockwell and Rockwell Superficial Hardness of Metallic Materials
- 2.8 ASTM E165: Standard Practice for Liquid Penetrant Inspection
- 2.9 ASTM E213: Standard Practice for Ultrasonic Examination of Metal Pipe and Tubing
- 2.10 ASTM E709: Standard Recommended Practice for Magnetic Particle Examination
- 2.11 ASTM E1268: Assessing the Degree of Banding or Orientation of Microstructures
- 2.12 Weatherford WH-020: Requirements for Bar Boring For ID Quenching
- 2.13 Weatherford Specification WH-231: Requirements for Quenching and Tempering 41XX type Steel to 110 ksi YS
- 2.14 Weatherford Specification WS-506: Cr-Mo-Ni Alloy steel – 110 ksi Minimum Yield Strength

## 3.0 MATERIAL PROPERTIES

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| TITLE:<br><b>4130 – 4145 Steel - 110 ksi Min. Yield Strength</b>                                      |                                |                           |                         |                                 | DATE:<br><b>9/14/2021</b> |                                                                                                      |

3.1 Chemical Composition: The chemical composition shall be determined in accordance with ASTM A751 and shall meet the requirements for the specific relevant Grade as listed in the Table below:

| Grade                                                                                                                                            |      | C    | Mn   | Si   | P     | S     | Cr   | Mo   | Ni (note 1) | Cu (Note 2) | Cb    |
|--------------------------------------------------------------------------------------------------------------------------------------------------|------|------|------|------|-------|-------|------|------|-------------|-------------|-------|
| 4130                                                                                                                                             | Min. | 0.28 | 0.40 | ---  | ---   | ---   | 0.80 | 0.15 | ---         | ---         | ---   |
|                                                                                                                                                  | Max. | 0.33 | 0.60 | 0.35 | 0.030 | 0.025 | 1.10 | 0.25 | 0.25        | 0.30        | ---   |
| 4140                                                                                                                                             | Min. | 0.38 | 0.75 | ---  | ---   | ---   | 0.80 | 0.15 | ---         | ---         | ---   |
|                                                                                                                                                  | Max. | 0.43 | 1.00 | 0.35 | 0.030 | 0.025 | 1.10 | 0.25 | 0.25        | 0.30        | ---   |
| 4142                                                                                                                                             | Min. | 0.40 | 0.75 | ---  | ---   | ---   | 0.80 | 0.15 | ---         | ---         | ---   |
|                                                                                                                                                  | Max. | 0.45 | 1.00 | 0.35 | 0.030 | 0.025 | 1.10 | 0.25 | 0.25        | 0.30        | ---   |
| 4145                                                                                                                                             | Min. | 0.43 | 0.75 | ---  | ---   | ---   | 0.80 | 0.15 | ---         | ---         | ---   |
|                                                                                                                                                  | Max. | 0.48 | 1.00 | 0.35 | 0.030 | 0.025 | 1.10 | 0.25 | 0.25        | 0.30        | ---   |
| 708M40                                                                                                                                           | Min. | 0.36 | 0.70 | 0.10 | ---   | ---   | 0.90 | 0.15 | ---         | ---         | ---   |
| 709M40                                                                                                                                           | Max. | 0.44 | 1.00 | 0.35 | 0.030 | 0.025 | 1.20 | 0.35 | 0.25        | 0.30        | ---   |
| 4130M                                                                                                                                            | Min. | 0.24 | 0.40 | ---  | ---   | ---   | 0.80 | 0.15 | ---         | ---         | ---   |
|                                                                                                                                                  | Max. | 0.37 | 1.20 | 0.40 | 0.030 | 0.025 | 1.50 | 0.75 | 0.25        | 0.30        | ---   |
| 4140M                                                                                                                                            | Min. | 0.38 | 0.75 | ---  | ---   | ---   | 0.80 | 0.15 | ---         | ---         | ---   |
|                                                                                                                                                  | Max. | 0.43 | 1.20 | 0.35 | 0.030 | 0.025 | 1.20 | 0.35 | 0.25        | 0.30        | ---   |
| 4145M                                                                                                                                            | Min. | 0.38 | 0.60 | ---  | ---   | ---   | 0.75 | 0.15 | ---         | ---         | ---   |
|                                                                                                                                                  | Max. | 0.49 | 1.25 | 0.40 | 0.030 | 0.025 | 1.50 | 0.75 | 0.25        | 0.30        | ---   |
| 30CrMoE                                                                                                                                          | Min. | 0.28 | 0.40 | 0.17 | ---   | ---   | 0.90 | 0.15 | ---         | ---         | ---   |
|                                                                                                                                                  | Max. | 0.34 | 0.70 | 0.37 | 0.030 | 0.025 | 1.20 | 0.25 | 0.25        | 0.30        | ---   |
| 35CrMo                                                                                                                                           | Min. | 0.32 | 0.40 | 0.17 | ---   | ---   | 0.80 | 0.15 | ---         | ---         | ---   |
|                                                                                                                                                  | Max. | 0.40 | 0.70 | 0.37 | 0.025 | 0.015 | 1.10 | 0.25 | 0.25        | 0.30        | ---   |
| 42CrMo                                                                                                                                           | Min. | 0.38 | 0.50 | 0.17 | ---   | ---   | 0.90 | 0.15 | ---         | ---         | ---   |
|                                                                                                                                                  | Max. | 0.45 | 0.80 | 0.37 | 0.030 | 0.025 | 1.20 | 0.25 | 0.25        | 0.30        | ---   |
| 41CrMo4                                                                                                                                          | Min. | 0.38 | 0.50 | 0.15 | ---   | ---   | 0.90 | 0.15 | ---         | ---         | ---   |
|                                                                                                                                                  | Max. | 0.44 | 0.80 | 0.40 | 0.025 | 0.025 | 1.20 | 0.30 | 0.25        | 0.30        | ---   |
| 42CrMo4                                                                                                                                          | Min. | 0.38 | 0.60 | ---  | ---   | ---   | 0.90 | 0.15 | ---         | ---         | ---   |
|                                                                                                                                                  | Max. | 0.45 | 0.90 | 0.40 | 0.025 | 0.025 | 1.20 | 0.30 | 0.25        | 0.30        | ---   |
| 40CrMnMo                                                                                                                                         | Min. | 0.37 | 0.90 | 0.17 | ---   | ---   | 0.90 | 0.20 | ---         | ---         | ---   |
|                                                                                                                                                  | Max. | 0.45 | 1.20 | 0.37 | 0.030 | 0.025 | 1.20 | 0.30 | 0.25        | 0.30        | ---   |
| Impact 7<br>Timken                                                                                                                               | Min  | 0.25 | 0.60 | 0.15 | ---   | ---   | 1.20 | 0.65 | ---         | ---         | 0.020 |
|                                                                                                                                                  | Max  | 0.35 | 0.90 | 0.35 | 0.025 | 0.005 | 1.50 | 0.75 | 0.25        | 0.30        | 0.050 |
| Note 1: Nickel needs only to be reported when added intentionally.                                                                               |      |      |      |      |       |       |      |      |             |             |       |
| Note 2: Copper needs only to be reported when added intentionally or when residual from steel making operations in concentrations $\geq 0.1\%$ . |      |      |      |      |       |       |      |      |             |             |       |

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| TITLE:<br>4130 – 4145 Steel - 110 ksi Min. Yield Strength                                                |                                |                    |                         |                          | DATE:<br>9/14/2021 |                                                                                                      |

- 3.2 Mechanical Properties: The surface hardness shall be as listed below as measured by ASTM E18 or ASTM E10. The mechanical properties at the mid-radius location shall be determined from a prolongation in accordance with ASTM A370 and shall meet the requirements listed in the Table below (test coupons are not permitted without Metallurgy review and approval): For raw material stock heat treated as a bar and there are ID threads that are further from the OD surface than the mid-radius, the mechanical properties shall be measured at the location representative of the smallest ID threads.

|                                                                                              | Yield Strength<br>Ksi (MPa) | Tensile Strength<br>ksi (MPa) | Elongation | Reduction<br>Of Area | Hardness<br>HRC (BHN) |
|----------------------------------------------------------------------------------------------|-----------------------------|-------------------------------|------------|----------------------|-----------------------|
| Min.                                                                                         | 110.0 (758)                 | 125.0 (862)                   | 15%        | 40%                  | 28.0 (269)            |
| Max.                                                                                         | See note 1                  | 165.0 (1138)                  | ---        | See note 2           | 37.0 (341)            |
| Note 1: The maximum yield strength to tensile strength ratio shall be 0.93.                  |                             |                               |            |                      |                       |
| Note 2: ROA is not required when strap type tensile specimens are used for tubular products. |                             |                               |            |                      |                       |

- 3.3 Melt Practice: Steels made to this specification shall be electric furnace melted and the steel shall be produced using melt and refining practices proven capable of producing steels that are free from deleterious defects. Basic oxygen furnace melting is an acceptable route if followed by vacuum degassing and ladle refining. The steel shall not exhibit a banded microstructure, when the microstructure is examined and evaluated in accordance with ASTM E1268, the anisotropy index (AI) shall not exceed 1.8.
- 3.4 Condition: The steel shall be furnished in the quenched and tempered condition. The minimum tempering temperature shall be 850°F (454°C).
- 3.5 Repair Welding: Repair welding is not permitted.
- 3.6 Section Size Considerations: Each of the low alloy steels listed in Section 3.1 exhibits a degree of hardenability that is a function of steel chemistry and processing. This inherent hardenability controls that maximum section size that can be effectively hardened. The limiting section thickness or size should be applied to the section thickness that is subjected to the highest stresses. The following Table lists the maximum section thickness for each of the materials to achieve the required 110 ksi yield strength throughout the entire section and through 80% of the section:

| Steel Grade                                                                                                                                                                               | Maximum Section Size by Alloy and Effective % |                |                |               |         |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------|----------------|----------------|---------------|---------|
|                                                                                                                                                                                           | 4130                                          | 4140           | 4142           | 4145          | 41xxM&H |
| Properties required through entire section                                                                                                                                                |                                               |                |                |               |         |
| Maximum bar OD                                                                                                                                                                            | 4" (10.2 cm)                                  | 4" (10.2 cm)   | 4.5" (11.4 cm) | 5" (12.7 cm)  | Varies  |
| Max. Section Thickness                                                                                                                                                                    | 1.0" (2.5 cm)                                 | 1.5" (3.8 cm)  | 1.5" (3.8 cm)  | 2" (5.1 cm)   | Varies  |
| Properties required through 80% of the section                                                                                                                                            |                                               |                |                |               |         |
| Maximum bar OD                                                                                                                                                                            | 4.5" (10.2 cm)                                | 5.5" (14.0 cm) | 5.5" (14.0 cm) | 6" (15.2 cm)  | Varies  |
| Max. Section Thickness                                                                                                                                                                    | 1.25" (3.2 cm)                                | 2.0" (5.1 cm)  | 2.25" (5.7 cm) | 2.5" (6.4 cm) | Varies  |
| <b>Note:</b> The maximum section thickness is defined as the distance from the original bar OD; a 1" limitation on a 4" bar means that the final product ID would need to be at least 2". |                                               |                |                |               |         |

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When bar is bored prior to heat treatment, the resultant wall could be treated as the section thickness, provided that (1) the part(s) through the austenitize and quench cycles are oriented in the vertical direction and (2) the minimum ID is in accordance Weatherford WH-020.

#### 4.0 SUPPLEMENTARY REQUIREMENTS

- 4.1 SUPPLEMENT 1 – Volumetric Non-Destructive Examination (NDE): When required by Purchase Order or Engineering Document, ultrasonic examination shall be performed in accordance with ASTM A388 for bar (both straight and angle beam inspection is required) and ASTM E213 for tube and bored bar. Note that bored bar and heavy wall tubulars must be inspected in accordance with the tube and bored bar requirements.
- 4.1.1 For straight beam inspection of bar, the calibration (distance amplitude curve or DAC) shall be based on a 1/16" (1.6 mm) flat bottomed hole for metal thickness up to 2" (5.1 cm) and 1/8" (3.2 mm) flat bottomed hole for metal thickness greater than 2" (5.1 cm). The acceptance criteria is as follows: (1) no single indications exceeding reference DAC and (2) no multiple indications exceeding 50% of the reference DAC within 1/2" (13 mm) of each other in any direction.
- 4.1.2 For angle beam inspection of bar, the calibration shall be performed by using 1/16" diameter 1" long side drilled holes. For tubular shapes, the calibration holes shall be 1/4" from the ID surface and 1/4" from the OD surface. For bars and solids, the calibration holes shall be 1" below the surface and the mid-radius. The acceptance criteria is no single indications exceeding reference standard.
- 4.1.3 For inspection of tube and bored bar: Ultrasonic examination shall be performed in accordance with ASTM E213. The rejection level calibration shall be established from 60 degree included-angle v-notches on the OD and ID of the tubular, with a depth no greater than 5% of the tubular wall thickness. The acceptance criterion is an absence of indications greater or equal to the rejection level.
- 4.2 SUPPLEMENT 2 – Cold Weather Toughness: When required by Purchase Order or Engineering Document, Charpy V Notch tests shall be performed at the mid-radius location at 14°F (-10°C) or lower in accordance with ASTM A370.
- 4.2.1 Bar: The minimum average impact energy is 31 ft-lbs (42 joules) with no single test result less than 22 ft-lbs (30 joules).
- 4.2.2 Tube and Bored Bar: When possible by tube dimensions, the impact tests shall run in the transverse direction. The minimum acceptable average impact value in the transverse direction shall be 15 ft-lbs (20 joules).

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When transverse tests cannot be conducted, longitudinal tests shall be run and the minimum acceptable average impact value in the longitudinal direction shall be 31 ft-lbs (42 joules).

4.2.3 Note that only one test may be below the average required and no single test shall be below 2/3 of the minimum average requirement.

4.3 SUPPLEMENT 3 – Surface Non-Destructive Examination (NDE): When required by Purchase Order or Engineering Document, surface inspection shall be performed in accordance with ASTM E165 (Liquid Penetrant) or ASTM E709 (magnetic particle – wet fluorescent technique only). The acceptance criteria is as follows: (1) no relevant linear indications, (2) no relevant rounded indications equal to or greater than 3/16" (5 mm), and (3) four or more rounded indications in a line separated by less than 1/16" (1.6 mm) measured edge to edge are unacceptable.

4.4 SUPPLEMENT 4 – Cold Weather Toughness: When required by Purchase Order or Engineering Document, Charpy V Notch tests shall be performed at -4°F (-20°C) or lower in accordance with ASTM A370. The minimum average impact energy is 20 ft-lbs (27 joules) with no single test result less than 15 ft-lbs (20 joules).

4.5 Supplement 6 – Hardness Variation and Hardenability: When required by Purchase Order or Engineering Document through wall hardness measurements shall be taken in accordance with the following:

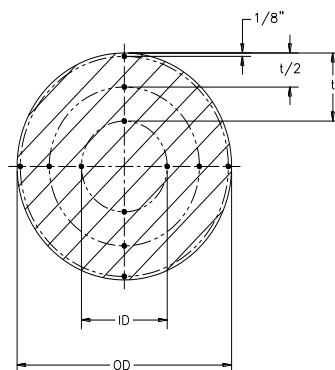
- 4.4.1 Hardness measurements shall be taken at multiple points in each quadrant as indicated the below figure.
- 4.4.2 For heat-treated bar stock or tubing, a test coupon shall be taken at a location of maximum thickness at least one radius from the end of bar stock or tubing.
- 4.4.3 For material that has been rough machined prior to heat-treatment, testing can be carried out on a heat/heat lot basis using a test coupon. The coupon shall be of similar OD and ID dimensions taken at a location of maximum wall thickness of the rough machined body. The length of the test coupon shall be at least equal to the coupon OD. The test coupon shall be sectioned mid-length and hardness measurements made across the cross-section at the mid-length location.
- 4.4.4 All hardness readings taken on a single cross-section shall be within a range of 6 HRC, with no values below 28 HRC (269 BHN). Hardness testing shall be conducted in accordance with ASTM E10 or ASTM E18 and the absolute values shall meet those shown in Section 3.2. Readings not meeting these requirements may be cause for material rejection.
- 4.4.4 One retest is allowed on the test coupon provided the coupon is faced-off to fully remove the initial hardness indentions and readings taken at the same locations. If the retest fails the entire heat lot shall be rejected.
- 4.4.5 Rejected material may be reprocessed along with another test coupon of the same heat lot and required dimensions and re-hardness tested in accordance with requirements herein or scrapped.

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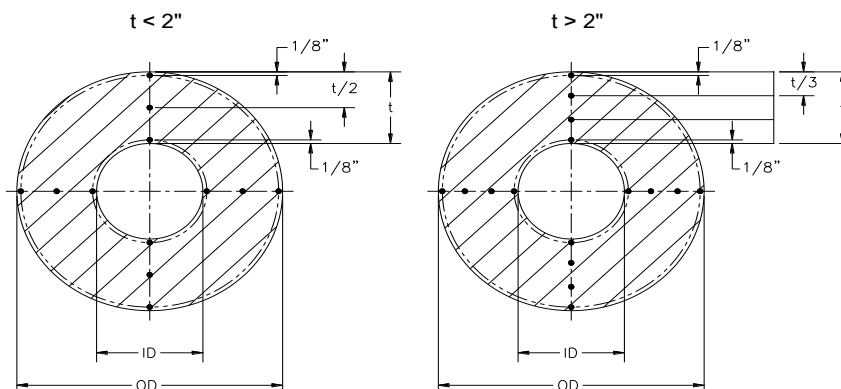
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a. Solid bar hardness test locations



b. Rough machines and tubing hardness test locations

- 4.6 SUPPLEMENT 8 – Restricted Alloy Ranges: When required by Purchase Order or Engineering Document, the carbon content shall be in the 0.36% - 0.44%. range (4140 type steels).
- 4.7 SUPPLEMENT 9 – Restricted Carbon Content: When required by Purchase Order or Engineering Document, the maximum carbon content shall be 0.43%.
- 4.8 SUPPLEMENT 11 – Special Heat Treatment / Stress Relieving: When required by Purchase Order or Engineering Document, the material ordered to this specification shall be in the normalized, hot worked or annealed conditions. After machining operations, the material shall be heat treated in accordance with WH-231.

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- #### 4.11.1 Transverse direction:

CVN Absorbed Energy in ft-lbs =  $21.3t+9.0$  where t = thickness of tube/bored bar at time of heat treatment.

- #### 4.10.2 Longitudinal direction:

CVN Absorbed Energy in ft-lbs =  $42.6t + 17.9$  where t = thickness of tube/bored bar at time of heat treatment.

- 4.10.3 The required minimum impact value will be the greater of two values: a) That given in Supplement 2 or b) As determined by the above equation for the direction of impact testing.

- 4.12 SUPPLEMENT 23 – Waiver of Specification Testing Requirements Except Hardness: When required by Purchase Order or Engineering Document, the tensile tests required by Section 3.2 are waived. The material shall be qualified by hardness tests in accordance with WH-231.
- 4.13 SUPPLEMENT 24 - Special Customer Dictated Requirements: When required by Purchase Order or Engineering Document, the composition requirements are further restricted in that chromium content shall be within the 0.8% - 1.2% range.
- 4.14 SUPPLEMENT 26 – Application Driven Special Requirements: When required by Purchase Order or Engineering Document, the strength level specified herein is required throughout the finished component structure; of critical importance are any ID threads. For raw material stock heat treated as a bar, mechanical properties shall be measured at the location representative of the ID threads. When there are multiple ID locations in a single structure, the location of the mechanical property tests shall be at the ID location furthest from the as-heat treated surface.

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| TITLE:<br><b>4130 – 4145 Steel - 110 ksi Min. Yield Strength</b>                                         |                                |                           |                         |                                 | DATE:<br><b>9/14/2021</b> |                                                                                                      |

- 4.15 SUPPLEMENT 28 – Test Location Requirements: When required by Purchase Order or Engineering Document, the mechanical tests performed for this material shall be taken at 1” below the heat treated surface (1/4T from a 5” equivalent round test coupon) or at the mid-radius.
- 4.16 SUPPLEMENT 35 – Material Substitution Based on Hardenability: When required by Purchase Order or Engineering Document, the material supplied to this specification is restricted to 4145. Substitutions to 4145 are acceptable only when the hardenability exceeds the minimum defined here. The hardenability, as defined by DI calculated per ASTM A255, shall be 100 mm minimum.
- 4.17 SUPPLEMENT 40 – Restricted Process Condition: When required by Purchase Order or Engineering Document, the material ordered to this specification shall have a tempering temperature that is 1125°F (607°C) or higher.
- 4.18 SUPPLEMENT 46 – Additional Toughness Tests: When required by Purchase Order or Engineering Document, Charpy V Notch tests shall be performed at ambient temperature or lower in accordance with ASTM A370. The minimum average impact energy is 30 ft-lbs (40 joules) with no single test result less than 25 ft-lbs (34 joules).
- 4.19 SUPPLEMENT 47 – Requirement for Preforming: When required by Purchase Order or Engineering Document, the material has to be heat treated (or re-heat treated if already heat treated) after rough machining to meet the specified mechanical properties of the specification. An allowance of 1/4” on all sizes shall be provided for final machining. Note that preforming may still be required to achieve mechanical properties when this Supplement is not activated; as assessment of the location of the smallest ID threads with the location of the mechanical property determination is required.
- 4.20 Supplement 62 – Additional Application Driven Special Requirements: When required by Purchase Order or Engineering Document, Charpy V Notch tests shall be performed at -26°F (-32°C) or lower in accordance with ASTM A370. The minimum average impact energy is 31 ft-lbs (42 joules) with no single test result less than 24 ft-lbs (34 joules).
- 4.21 Supplement 63 – Additional Test location Requirements: When required by Purchase Order or Engineering Document, all test pieces shall be taken from a prolongation cut from a position at least 1 times the diameter away from the end of the bar. For material heat treated as a solid, test specimens to be removed from a 3" diameter location and for material heat treated as a hollow all test specimens to be taken from the mid-wall location
- 4.22 SUPPLEMENT 65 - Specific or Restricted Alloy Grades: When required by Purchase Order or Engineering Document, material selection shall be limited to non-modified grades, e.g. 4130, 4140.
- 4.23 SUPPLEMENT 67 - Additional Application Driven Special Requirements: When required by Purchase Order or Engineering Document, the chromium content range shall be restricted to 0.9% – 1.2 %.

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| <br><b>Weatherford®</b> | <b>MATERIALS SPECIFICATION</b> |                           |                         |                                 |                           |                                                                                                      |
|                                                                                                          | REV:<br><b>AU</b>              | SECTION:<br><b>Steels</b> | NUMBER<br><b>WS-412</b> | Prepared by:<br><b>W. Howie</b> | PAGE<br><b>9</b>          | APPROVAL:<br><br> |
| TITLE:<br><b>4130 – 4145 Steel - 110 ksi Min. Yield Strength</b>                                         |                                |                           |                         |                                 | DATE:<br><b>9/14/2021</b> |                                                                                                      |

## 5.0 QUALITY REQUIREMENTS

- 5.1 Traceability: The heat identification shall be maintained through all stages of processing. All parts shall be traceable to the heat treat batch and heat lot.
- 5.2 Visual Inspection: The bar and shaped products shall be free of deleterious cracks, laps, seams or other defects. All parts containing these defects shall be considered discrepant and are cause for rejection.
- 5.3 Straightness: The straightness shall be within 1/8" in every 5'.
- 5.4 Test Requirements: Test requirements including frequency, test location and prolongation requirements shall be in accordance with this section. The tensile and impact tests (when required) shall be determined from a prolongation or test bar sized such that the entire tested gauge section is at least as far from any heat treated surface as the mid-radius location. This requirement is translated as the same diameter with a minimum test bar or prolongation length that shall be the bar diameter minus 2 inches. For bar diameters that are 8" and less, the test bar or prolongation length shall be at least 6". As an example for a 12" diameter bar, this is 12" – 2" = 10" minimum test bar length. The tests required with frequency are defined in the following Table:

| Test Required         | Test Frequency                      | Method & Acceptance Reference |
|-----------------------|-------------------------------------|-------------------------------|
| Tensile Properties    | Once per heat & heat treat batch    | Paragraph 3.2                 |
| Surface Hardness      | Once, each length or piece          | Paragraph 3.2                 |
| Composition           | Once per heat                       | Paragraph 3.1                 |
| Impact Toughness      | One set per heat & heat treat batch | Supplement 2, 4, 22, 46 or 62 |
| Volumetric Inspection | 100% volumetric                     | When required by Supplement 1 |
| Surface NDE           | 100% MPI or LPI                     | When required by Supplement 3 |
| Through-wall Hardness | Once per heat or heat treat batch   | When required by Supplement 6 |
| Surface Inspection    | 100% visual                         | Paragraph 5.2                 |

- 5.5 Certification: Certifications shall be supplied for each shipment. The certification shall include as a minimum the following: heat treat batch number or code, heat identification, test results per Section 5.4, and Purchase Order Number.

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